# Underweight Increases the Risk of End-Stage Renal Diseases for Type 2 Diabetes in Korean Population: Data From the National Health Insurance Service Health Checkups 2009-2017

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## OBJECTIVE

**There is a controversy over the association between obesity and end-stage renal disease (ESRD) in people with or without type 2 diabetes; therefore, we examined the effect of BMI on the risk of ESRD according to glycemic status in the Korean population.**

## RESEARCH DESIGN AND METHODS

**The study monitored 9,969,848 participants who underwent a National Health Insurance Service health checkup in 2009 from baseline to the date of diagnosis of ESRD during a follow-up period of ∼8.2 years. Obesity was categorized by World Health Organization recommendations for Asian populations, and glycemic status was categorized into the following five groups: normal, impaired fasting glucose (IFG), newly diagnosed diabetes, diabetes <5 years, and diabetes ≥5 years.**

## RESULTS

**Underweight was associated with a higher risk of ESRD in all participants after adjusting for all covariates. In the groups with IFG, newly diagnosed type 2 diabetes, diabetes duration <5 years, and diabetes ≥5 years, the hazard ratio (HR) of the underweight group increased with worsening glycemic status (HR 1.431 for IFG; 2.114 for newly diagnosed diabetes; 4.351 for diabetes <5 years; and 6.397 for diabetes ≥5 years), using normal weight with normal fasting glucose as a reference. The adjusted HRs for ESRD were also the highest in the sustained underweight group regardless of the presence of type 2 diabetes (HR 1.606 for nondiabetes, and 2.14 for diabetes).**

## CONCLUSIONS

**Underweight showed more increased HR of ESRD according to glycemic status and diabetes duration in the Korean population. These associations also persisted in the group with sustained BMI during the study period.**


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Type 2 diabetes and obesity have emerged as enormous public health problems all over the world (1–3). Type 2 diabetes is one of the leading causes of chronic kidney disease (CKD) and end-stage renal disease (ESRD) (4). ESRD also has emerged as a public health problem, as the number of ESRD patients has increased very rapidly worldwide (5,6), and patients with ESRD have experienced high rates of morbidity and mortality.

ESRD is defined as a glomerular filtration rate (GFR) $<$15 mL/min/1.73 $m^2$ and as a condition requiring hemodialysis or kidney transplantation (7). The risk factors for ESRD are older age, proteinuria, smoking, lower educational attainment, family history of kidney disease, lower hemoglobin level, higher serum uric acid level, acute kidney injury, hypertension, type 2 diabetes, and obesity, although there are ethnic differences (8–10).

There is much evidence showing obesity as an independent risk factor of ESRD, regardless of the presence of type 2 diabetes (11), and most observational studies have shown positive associations between obesity and CKD or ESRD (12–15). However, some epidemiologic studies have found inverse associations between obesity and ESRD (16,17). In addition, few studies have compared the effect of obesity on the risk of ESRD in subjects with and without type 2 diabetes (13). Therefore, we aimed to evaluate the association between BMI and the risk of ESRD according to glycemic status in Koreans using the National Health Insurance Service (NHIS) health checkup data. We also examined the association between BMI and the risk of ESRD according to the presence of type 2 diabetes in sustained BMI groups (participants who maintained their weight during the study period), because high variability of BMI was associated with the development of ESRD in the general population (18).

## RESEARCH DESIGN AND METHODS

### The NHIS Database and NHIS Health Checkup Program

The NHIS collects medical information from ~50 million Koreans and is a single insurer that manages the National Health Insurance program. The NHIS collects patients' demographic data, such as region, age, sex, medical utilization/transaction information, claims and deduction data, and insurers' payment coverage. The NHIS database has data for ~97.0% of the Korean population's health insurance claims. The NHIS database has been described in detail in previous studies (19,20).

The NHIS also manages a biennial health checkup program for all insured Koreans $>$40 years of age, and employee subscribers who are $>$20 years of age are recommended to have the NHIS health checkup every year. The NHIS health checkup program has four possible components: general health checkup, baby/infant health checkup, cancer checkup, and lifetime transition period health checkup. The NHIS health checkup programs include anthropometric measurements, hearing and visual acuity checks, laboratory tests, past family, medical, and surgical history, and social history. Hospitals perform the health checkups after being certified by the NHIS, which also regularly qualifies trained examiners.

### Study Population

We used the NHIS health checkup database from 2002 to 2017. We selected subjects who were $>$20 years and who had undergone health checkups in 2009. We monitored subjects until 31 December 2017 ($n$ = 10,505,818). We excluded those who were $<$20 years old ($n$ = 15,327), those with missing data ($n$ = 511,930), those with type 1 diabetes ($n$ = 1,282), and those with a history of ESRD before the health checkup ($n$ = 7,431). Finally, 9,969,848 subjects (5,462,258 men and 4,507,590 women) were included in this study, and the mean observation time was 8.2 $\pm$ 0.8 years (Supplementary Fig. 1 and Supplementary Table 4). This study was approved by the Korea University Anam Hospital Institutional Review Board (IRB No. ED17115), and permission was granted to use the NHIS health checkup data (NHIS-2017-4-006). De-identified and anonymized data were used for analyses.

### Definition of CKD and ESRD

CKD and ESRD were defined as a GFR of $<$60 and 15 mL/min/1.73 $m^2$, respectively, and as a combination of ICD-10 codes (N18-19, Z49, Z94.0, and Z99.2) and special codes (V codes) such as codes for peritoneal dialysis (V003), hemodialysis (V001), or kidney transplantation (V005), which are all assigned to CKD patients (21). The estimated GFR (eGFR) was calculated based on the CKD epidemiology collaboration (CKD-EPI) equation: eGFR (mL/min/1.73 $m^2$) = 141 $\times$ min (serum creatinine/$\kappa$, 1)$^{\alpha}$ $\times$ max (serum creatinine/$\kappa$, 1)$^{-1.209}$ $\times$ 0.993$^{age}$ $\times$ 1.018 [if female] $\times$ 1.159 [if African American], where $\kappa$ is 0.7 for females and 0.9 for males, $\alpha$ is $-$0.329 for females and $-$0.411 for males, min indicates the minimum value of serum creatinine/$\kappa$ or 1, and max indicates the maximum value serum creatinine/$\kappa$ or 1. The study participants were monitored from baseline to the date of diagnosis of ESRD because the primary end point was the incidence of ESRD (22).

### Assessment of Obesity

BMI was calculated by dividing the weight by square of the height and was categorized by the definition of obesity as follows: underweight (BMI $<$18.5 kg/$m^2$), normal weight (BMI 18.5–23 kg/$m^2$), overweight (BMI 23–25 kg/$m^2$), obesity stage I (BMI 25–30 kg/$m^2$), and obesity stage II (BMI $\geq$30 kg/$m^2$) according to the World Health Organization (WHO) recommendations for Asian populations (23). The sustained BMI group was defined as participants who kept their weight in the same BMI groups for 1 year beginning the date of the health checkup in 2009 according to WHO recommendations during the study period.

### Glycemic Status and Definition of Chronic Diseases

All participants were categorized into five groups based on their glycemic status: normal, impaired fasting glucose (IFG), newly diagnosed type 2 diabetes, diabetes $<$5 years, and diabetes $\geq$5 years (Supplementary Fig. 1). IFG was defined as a fasting plasma glucose (FPG) level of 100–125 mg/dL. Type 2 diabetes was defined as an FPG level $\geq$126 mg/dL or at least one claim per year for the prescription of hypoglycemic drugs under ICD-10 codes E11–14 (24,25). Patients with type 1 diabetes who had claims under ICD-10 code E10 were excluded from this study (26,27). Newly diagnosed diabetes was defined as those diagnosed with diabetes at the time of national health examinations in 2009. The group with diabetes $<$5 years was defined as those who had type 2 diabetes within 5 years on the date of the health checkup in 2009, that is to say, the patients with

**Table 1—Baseline characteristics of 9,969,848 subjects with and without type 2 diabetes**

| Variables | No diabetes $n$ = 9,101,607 | Type 2 diabetes $n$ = 868,241 | $P$ |
|---|---|---|---|
| Age (years) | 46.18 ± 13.91 | 57.42 ± 12.04 | <0.001 |
| Men | 4,928,604 (54.15) | 534,109 (61.48) | <0.001 |
| Height (cm) | 164.02 ± 9.21 | 162.45 ± 9.18 | <0.001 |
| Weight (kg) | 63.7 ± 11.57 | 66.22 ± 11.5 | <0.001 |
| BMI (kg/m$^2$) | 23.58 ± 3.17 | 25.01 ± 3.27 | <0.001 |
| WC (cm) | 79.73 ± 8.97 | 85.48 ± 8.39 | <0.001 |
| SBP (mmHg) | 121.78 ± 14.72 | 129.1 ± 15.68 | <0.001 |
| DBP (mmHg) | 76.03 ± 9.92 | 79.07 ± 10.13 | <0.001 |
| Glucose (mg/dL) | 92.53 ± 11.5 | 145.41 ± 45.6 | <0.001 |
| Total cholesterol (mg/dL) | 194.82 ± 36.08 | 197 ± 41.64 | <0.001 |
| Triglyceride (mg/dL)* | 110.67 ± 9.57 | 150.15 ± 11.5 | <0.001 |
| HDL-cholesterol (mg/dL) | 55.74 ± 18.66 | 51.77 ± 11.18 | <0.001 |
| eGFR (mL/min/1.73 m$^2$) | 88.75 ± 44.78 | 83.97 ± 35.09 | <0.001 |
| CKD | 486,676 (5.35) | 102,415 (11.79) | <0.001 |
| Glucose status | | | <0.001 |
| Normal | 6,843,288 (75.19) | — | |
| IFG | 2,258,319 (24.81) | — | |
| Diabetes | | | |
| New-onset | — | 293,163 (33.77) | |
| <5 years | — | 299,389 (34.48) | |
| ≥5 years | — | 275,689 (31.75) | |
| BMI (kg/m$^2$) | | | <0.001 |
| <18.5 | 366,350 (4.03) | 12,951 (1.49) | |
| 18.5–23 | 3,705,102 (40.71) | 220,047 (25.34) | |
| 23–25 | 2,245,509 (24.67) | 223,095 (25.7) | |
| 25–30 | 2,500,352 (27.47) | 352,156 (40.56) | |
| ≥30 | 284,294 (3.12) | 59,992 (6.91) | |
| Hypertension | 2,067,523 (22.72) | 497,770 (57.33) | <0.001 |
| Dyslipidemia | 1,464,266 (16.09) | 356,864 (41.1) | <0.001 |
| Smoking | | | <0.001 |
| Non | 5,447,316 (59.85) | 483,354 (55.67) | |
| Former | 1,271,382 (13.97) | 159,663 (18.39) | |
| Current | 2,382,909 (26.18) | 225,224 (25.94) | |
| Alcohol drinking | | | <0.001 |
| Non | 4,642,563 (51.01) | 494,678 (56.97) | |
| Mild | 3,850,412 (42.3) | 298,946 (34.43) | |
| Heavy | 608,632 (6.69) | 74,617 (8.59) | |
| Regular exercise | 4,699,115 (51.63) | 426,070 (49.07) | <0.001 |
| Income (Q1) | 2,391,515 (26.28) | 235,406 (27.11) | <0.001 |

Continuous data are presented as the mean ± SD and categorical data as $n$ (%). DBP, diastolic blood pressure; SBP, systolic blood pressure. *Log transformation.

newly diagnosed type 2 diabetes from 2004 to 2008. The group with diabetes ≥5 years was defined as those who had type 2 diabetes 5 years before in 2009; namely, the patients with newly diagnosed type 2 diabetes before 2003. Hypertension was defined as a blood pressure ≥140/90 mmHg or at least one claim per year for antihypertensive medication prescription under ICD-10 codes I10–I15. Dyslipidemia was defined by total cholesterol ≥240 mg/dL or at least one claim per year for the prescription of antidyslipidemic agents under ICD-10 code E78.

### General Health Behaviors and Sociodemographic Variables

Smoking history was categorized as nonsmokers, former smokers, and current smokers. Alcohol drinking was categorized into 0, 1 to ~2, or ≥3 times/week (none, mild, and heavy, respectively), and regular exercise, defined as vigorous physical activity for at least 20 min/day, was categorized into 0, 1 to ~4, and ≥5 times/week by frequency. Income level was divided by quartile: Q1 (the lowest), Q2, Q3, and Q4 (the highest).

### Statistical Analysis

The general characteristics of subjects are expressed as means ± SD for continuous variables and percentage (SD) for categorical variables between subjects with and without type 2 diabetes. The hazard ratios (HRs) and 95% CIs for ESRD by BMI category and sustained BMI group were obtained using multivariable Cox proportional hazard models using the normal BMI (BMI 18.5–23 kg/m$^2$) as a reference after adjusting for age, sex, smoking, alcohol drinking, regular exercise, type 2 diabetes, hypertension, dyslipidemia, CKD, income (Q1), glucose, and waist circumference (WC). We did interaction analysis also. The incidence rate (IR) per 1,000 person-years was calculated, and the HR and 95% CI for ESRD by glucose status according to BMI category was also obtained by constructing multivariable Cox proportional hazard models using the normal weight in nondiabetes as a reference after adjusting for all covariates. Subgroup analyses was also performed by multivariable Cox proportional hazard models dividing subjects by age ≥65 years or not, men or women, smoking or not, and CKD or not using nonunderweight as a reference after adjusting for all covariates. We did interaction analysis between age (alternatively sex, smoking, CKD) and underweight separately for nondiabetes and type 2 diabetes. All statistical analyses were calculated using SAS 9.3 software (SAS Institute, Cary, NC), and all two-tailed $P$ <0.05 were considered statistically significant.

## RESULTS

### Characteristics of the Study Population

The analysis included 9,969,848 patients. During the mean follow-up duration of 8.2 ± 0.8 years (82,166,630 patient * years follow-up), there were 34,094 individuals with newly diagnosed ESRD. Table 1 reports the baseline characteristics of participants according to the presence of type 2 diabetes. Diabetes was diagnosed in 868,241 patients (8.71%): 293,163 as newly diagnosed; 299,389 as <5 years diabetes; and 275,689 as >5 years diabetes. Subjects with type 2 diabetes were older and shorter. They had increased weight, BMI, WC, systolic and diastolic blood pressure, glucose, total cholesterol, and triglycerides. They had an increased proportion of men, heavy alcohol drinkers, former smokers, income

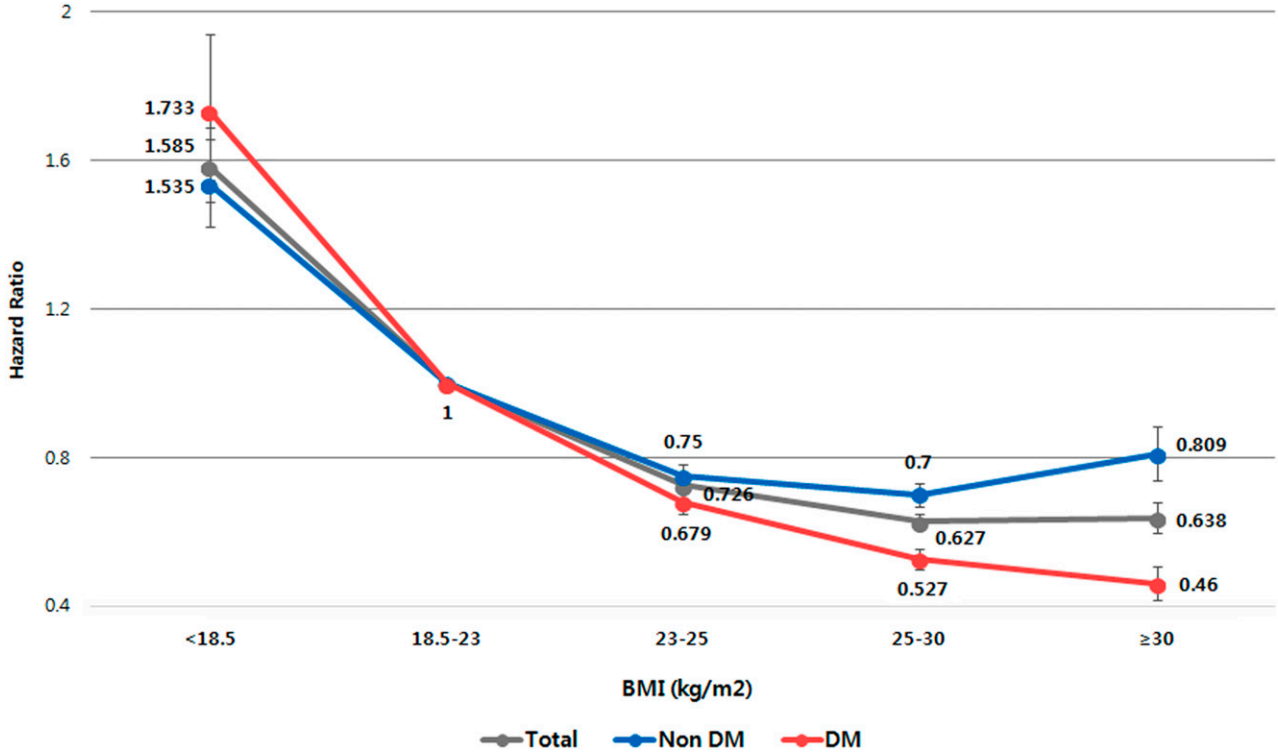


**Figure 1**—Adjusted HRs of ESRD for each category of BMI for the subjects with and without type 2 diabetes (DM), adjusted for age, sex, smoking, alcohol drinking, regular exercise, income, type 2 diabetes, hypertension, dyslipidemia, CKD, glucose, and WC. All *P* for interaction <0.001.

(Q1), chronic diseases such as hypertension, dyslipidemia, and CKD, overweight status, and obesity (BMI ≥25 kg/m$^2$) (all $P < 0.001$). They had decreased HDL-cholesterol and eGFR, and a decreased proportion of regular exercise, underweight status, and normal weight (all $P < 0.001$).

### Risk of ESRD for Each Category of BMI According to the Presence of Type 2 Diabetes

The HR of ESRD increased as BMI decreased. The HR was highest in the underweight group (HR 1.602; 95% CI 1.504–1.706) and lowest in the obesity stage 1 group (HR 0.627; 95% CI 0.606–0.649), after adjusting for all baseline covariates (age, sex, smoking, alcohol drinking, regular exercise, income, type 2 diabetes, hypertension, dyslipidemia, CKD, glucose, and WC) (Fig. 1 and Supplementary Table 1). In the underweight group, participants with type 2 diabetes had a higher HR of ESRD (HR 1.733) compared with those without type 2 diabetes (HR 1.535), after adjusting for all covariates. However, in the overweight, obesity stage I, and obesity stage II groups, participants without type 2 diabetes had a higher HR of ESRD compared with those with type 2 diabetes, after adjusting for all covariates (HR 0.75, 0. 7, and 0.809 in those without type 2 diabetes and 0.679, 0.525, and 0.46 in those with type 2 diabetes, respectively) (all *P* for interaction <0.001).

### Effect of BMI on the Risk of ESRD According to Glycemic Status

We also analyzed the IR (per 1,000) and HR of ESRD by BMI category, stratified based on fasting glucose and diabetes duration, as shown in Fig. 2 (Supplementary Table 3). In the group with normal fasting glucose, the IR (per 1,000 person-year) was highest in the obesity stage II group (IR 0.315). However, in the groups with IFG, newly diagnosed type 2 diabetes, diabetes <5 years, and diabetes ≥5 years, the IR was the highest in underweight group and increased with worsening glycemic status (IR 0.46 for IFG; 1.415 for newly diagnosed type 2 diabetes; 3.807 for diabetes <5 years; and 6.954 for diabetes ≥5 years). In the groups with IFG, newly diagnosed type 2 diabetes, diabetes duration <5 years, and diabetes duration ≥5 years, the HR of underweight group increased with worsening glycemic status (HR 1.431 for IFG, 2.114 for newly-diagnosed diabetes, 4.351 for diabetes <5 years, and 6.397 for diabetes ≥5 years), using normal weight with normal fasting glucose as a reference.

### Subgroup Analysis of Risk of ESRD in the Underweight Group According to Type 2 Diabetes Status

We examined the incidence of ESRD in the underweight group by subgroups of age, sex, smoking, and CKD (Supplementary Table 2). The HR of ESRD was significantly higher in subjects <65 years than subjects ≥65 years (HR 2.316 in type 2 diabetes and 1.719 in nondiabetes and both *P* for interaction <0.005). HR was higher in men in subjects without diabetes but lower in men with in type 2 diabetes; however, the HRs were not significantly different in subjects without and with type 2 diabetes. Subjects with a history of smoking had a lower HR than nonsmokers, but this was not statistically significant. The HR was lower in subjects with CKD in subjects with type 2 diabetes (HR 1.436, *P* for interaction <0.001).

### Risk of ESRD for Sustained BMI Groups According to Type 2 Diabetes Status

To minimize the effect of the variability of BMI on ESRD, we examined the risk of ESRD in sustained BMI groups

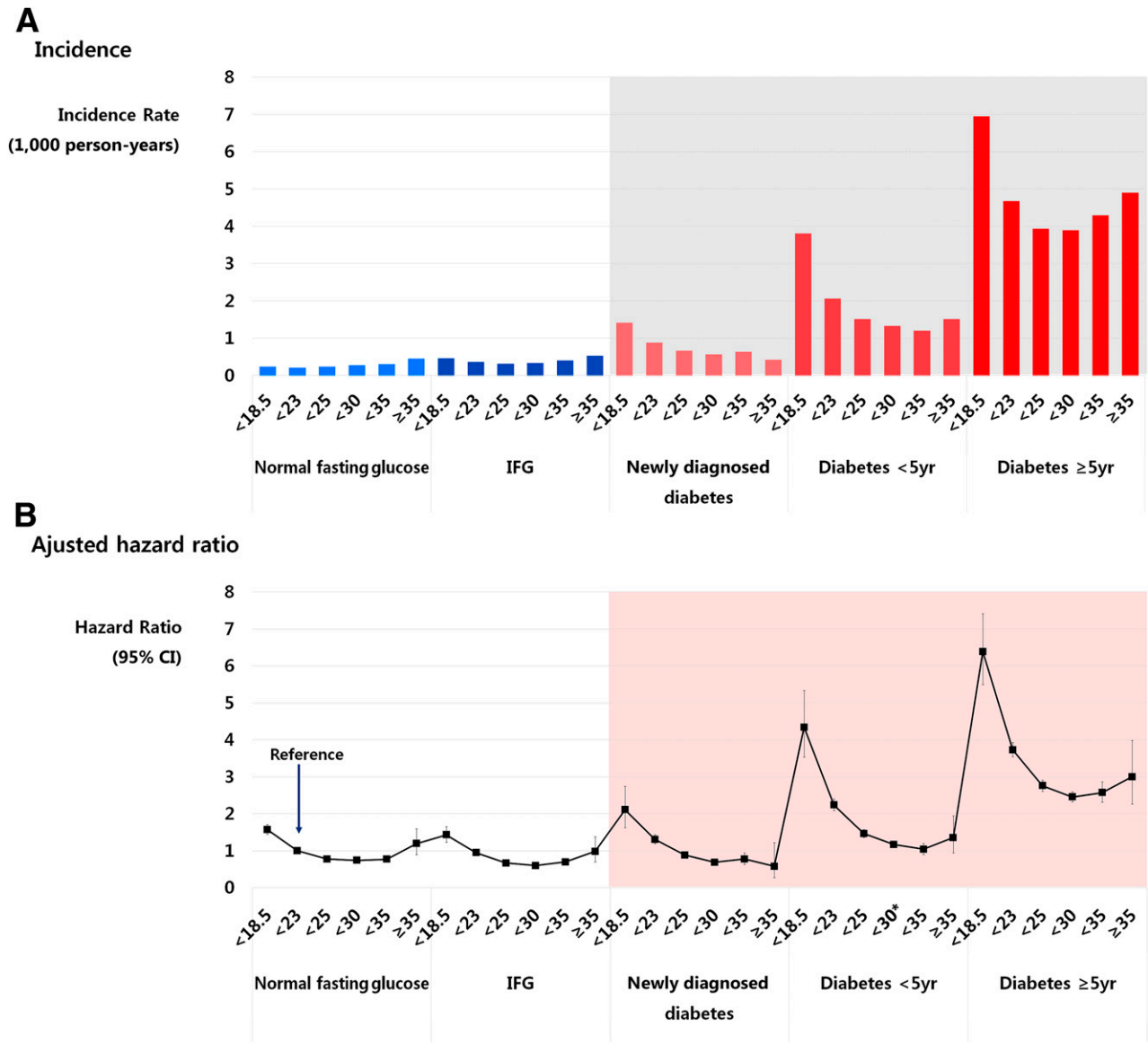


**Figure 2**—IR of ESRD per 1,000 person-years (*A*) and adjusted HRs of ESRD (*B*) for each category of BMI according to glycemic status, Adjusted for age, sex, smoking, alcohol drinking, regular exercise, income, type 2 diabetes, hypertension, dyslipidemia, CKD, glucose, and WC. *Statistically not significant.

according to the presence of type 2 diabetes, as shown in Fig. 3 (Supplementary Table 5). A total of 325,0627 participants were in sustained BMI groups: 112,279 as underweight, 1,402,030 as normal weight, 671,920 as overweight, 960,973 as obesity stage I, and 103,425 as obesity stage II. The HR for ESRD was highest in subjects with sustained underweight status regardless of the presence of type 2 diabetes (HR 1.606 for nondiabetes and 2.14 for type 2 diabetes). In the group without type 2 diabetes, the HR for ESRD showed a reverse J-curve. However, the HR of ESRD in the group with type 2 diabetes decreased as BMI increased.

## CONCLUSIONS

In this nationwide population-based cohort study, the risk of ESRD is increased in patients with obesity and underweight, and underweight showed more increased HR of ESRD according to glycemic status in the Korean population during an ~8.2-year follow-up period. We also observed a strong association between lower BMI and the risk of ESRD according to type 2 diabetes status and the diabetes duration. These associations persisted in the group with sustained BMI and after multivariable adjustment, including all baseline covariates (age, sex, smoking, alcohol drinking, regular exercise, income, type 2 diabetes, hypertension, dyslipidemia, CKD, glucose, and WC).

Several studies have examined the association between BMI and future risk of ESRD (12–14,17,28–30). Although the results are conflicting, most epidemiologic studies showed that higher BMI was associated with an increased risk of kidney disease (12–14,28,30), and our findings are inconsistent with those previously published studies. Two large epidemiologic studies in the U.S. reported a positive association between BMI and ESRD, and because these studies analyzed a broad spectrum of BMI among a large, diverse sample of participants with long-term follow-up for ESRD (12,13),

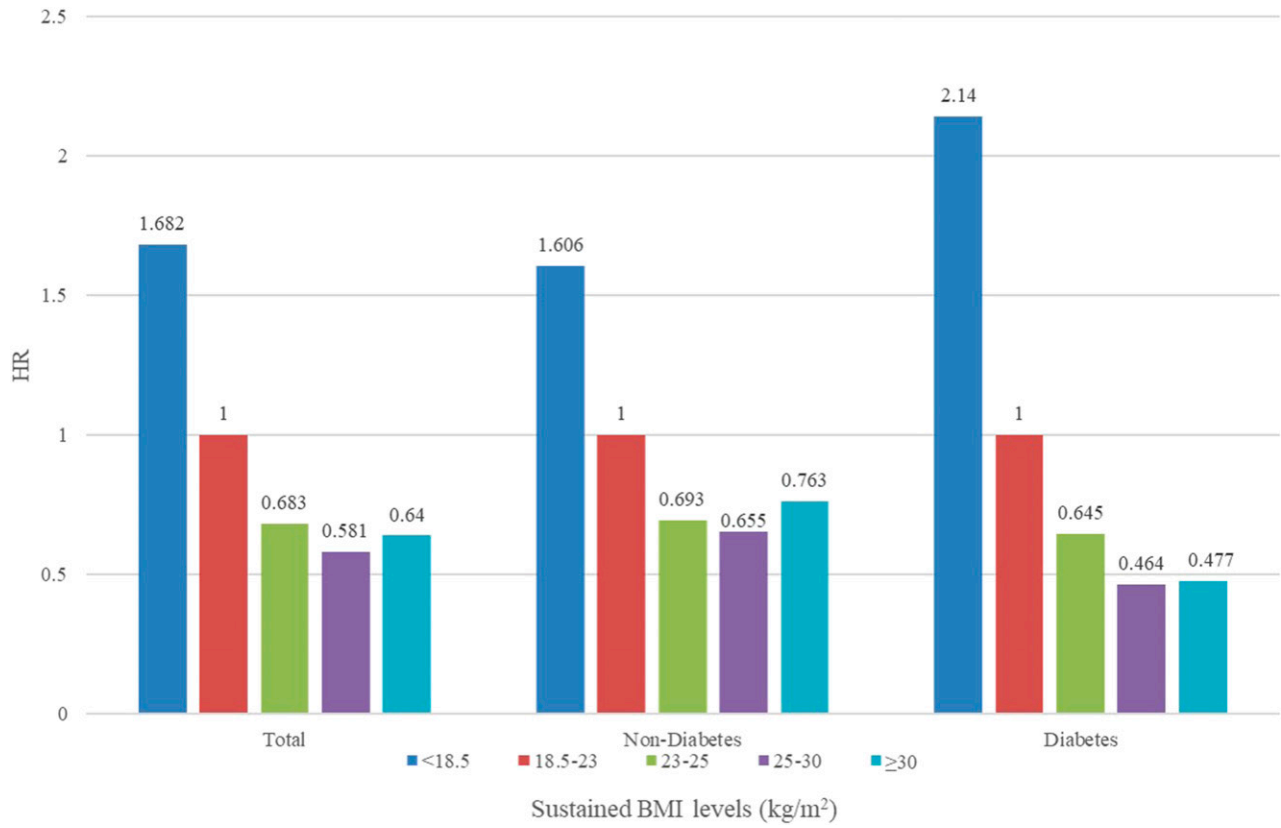


**Figure 3**—Adjusted HRs of ESRD in the groups with sustained BMI with or without type 2 diabetes. Adjusted for age, sex, smoking, alcohol drinking, regular exercise, income, type 2 diabetes, hypertension, dyslipidemia, CKD, glucose, and WC.

it has been thought that higher BMI is an independent risk factor of ESRD in any racial/ethnic group. In contrast, fewer studies have found an association between lower BMI and future risk of ESRD. Two Asian studies showed a reverse association between BMI and renal problems (17,29). However, because these studies were retrospective cross-sectional studies, the authors believed that lower BMI might not lead to development of renal problems and instead suggested the possibility that renal problems may lead to malnutrition or weight loss. We therefore considered that longitudinal studies are required to explore the actual relationship between BMI and the risk of ESRD. To the best of our knowledge, this is the first nationwide cohort study to examine the relationship between lower BMI and the risk of ESRD according to type 2 diabetes status in the Korean general population.

There is recent interest in intraindividual variability in metabolic parameters, such as fasting blood glucose and body weight, as putative risk factors for chronic disease including ESRD (18,31). Weight changes, regardless of increase or decrease, have been associated with increased mortality (32–34). In the Framingham Heart Study, participants with a high variability of body weight had increased all-cause mortality and mortality due to coronary heart disease (35). One study of kidney disease showed that variability in body weight was associated with the development of ESRD (18). In order to minimize the effects of intravariability in body weight, we examined the risk of ESRD for each category of BMI according to the presence of type 2 diabetes in sustained BMI groups during the study period, and the HR was the highest in the underweight group in all participants after adjusting for baseline covariates. These results are the same as those in the general population in this study. Longitudinal studies are needed to evaluate the association between body weight change and the future risk of ESRD.

It is well known that diagnosed type 2 diabetes is an important risk factor of ESRD (4), but few studies have evaluated the association between newly diagnosed type 2 diabetes and the risk of ESRD (36), although renal problems may be present at the time of diagnosis of type 2 diabetes (37). Our results showed that the risk of ESRD was significantly higher in the group with type 2 diabetes than in the group without diabetes and also revealed the relationship between newly diagnosed type 2 diabetes and the future risk of ESRD (Fig. 2).

The recent Action in Diabetes and Vascular Disease: Preterax and Diamicron Modified-Release Controlled Evaluation (ADVANCE) trial showed that higher BMI is an independent predictor of major renal events in patients with type 2 diabetes (14). At first glance, their results seemed to differ from ours. However, there are some basic differences between the two studies. First, because the results in the ADVANCE trial were compared with participants with normal weight, namely, they excluded the underweight participants, they could not explain the effect of underweight status on the risk of ESRD. Second, the inclusion criteria in the ADVANCE trial were a diagnosis of type 2 diabetes at ≥30 years of age, a history of major macrovascular or microvascular disease or at least one other risk factor for vascular disease, and the diabetes duration in the

participants was ~8 years (38). Therefore, we compared the results of that study with those of the participants with diabetes duration of >5 years in our study (Fig. 2) and found similar results, except in the case of underweight participants.

The exact mechanism of the relationship between BMI and future risk of ESRD remains unclear. One study that showed an association between higher baseline BMI and ESRD suggested that people with higher BMI are likely already to have hypertension or type 2 diabetes and are also more likely to develop hypertension or type 2 diabetes, because these factors are known independent risk factors for ESRD (13). How might we explain our results, which are inconsistent with results of other studies? It is likely that our inconsistent findings were partly due to ethnic differences. Several studies showed that Asians have a higher body fat percentage and are at higher risk for type 2 diabetes, hypertension, and heart disease than other people with the same BMI level (39,40). Furthermore, at an early stage in the increment of visceral fat percentage in some Asian populations, the risk of hyperglycemia is greater than for Europeans of the same age (41,42). Therefore, because Asian people are likely to develop type 2 diabetes at a lower BMI and at younger ages and suffer longer with complications (1), lower BMI may not necessarily guarantee health in Asian populations. The Asia-Pacific guideline for the diagnostic criteria of obesity was established based on these findings (23), and we used these criteria in our study.

This study has several strengths. First, it is the first study to examine the association between BMI and the risk of ESRD according to type 2 diabetes status in the Korean population. Second, this study had a large sample size and used a well-validated longitudinal national database. Third, it also included important anthropometric measurements and biochemical parameters.

However, there are some limitations in this study. First, we did not collect relevant information on food habits or other comorbidities that might affect weight. Second, this study did not consider first-time identification of type 2 diabetes, use of medications such as hypoglycemic agents or lipid-lowering agents, and adherence to treatment. Third, we could not consider any change in body weight and glucose (variability in weight and glucose) during the follow-up period. Fourth, we were unable to obtain more information about the causes of ESRD. Fifth, we used data of the NHIS checkup program; therefore, we cannot generalize the results to other ethnic groups, because this study only included the Korean population. Sixth, although we monitored subjects for 8.2 years, the time of follow-up is short for patients with newly diagnosed diabetes to develop ESRD.

Larger studies over a longer time are needed to provide a more definitive answer about whether lower BMI is a risk factor for ESRD and whether there are racial differences in this association. The results of this nationwide population-based cohort study add evidence that low BMI is associated with a higher risk of ESRD development according to the type 2 diabetes status and the duration of type 2 diabetes. We also showed that these associations persisted in the groups with sustained BMI during the study period. Further research is also required to elucidate the mechanism behind the association between BMI and ESRD and to confirm whether lower BMI is a significant target for identifying high-risk patients.

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